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PROCEEDINGS OF GOVERNORS' CONFERENCE ON HEALTH HAZARDS IN URANIUM MINES HELD IN DENVER, COLORADO 16 DECEMBER 1960

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Governors' Conference on Health Hazards in Uranium Mines

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A Summary Report

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U.S. DEPARTMENT OF HEALTH, EDUCATION AND WELFARE
Public Health Service
Bureau of State Services
Division of Occupational Health

FOREWORD

This report is based on the proceedings of a meeting of the Governors and their representatives of those States engaged in uranium mining, called by the Secretary of Health, Education, and Welfare, in Denver, Colorado, December 16, 1960. The States participating were Arizona, Colorado, Montana, New Mexico, South Dakota, Utah, and Wyoming. An outgrowth of inter-departmental studies of the occupational health problems of uranium miners made over a period of years by the Public Health Service, the Atomic Energy Commission, the Bureau of Mines, and the Department of Labor, the conference had a three-fold purpose: (1) to make known provocative data concerning the health of uranium miners; (2) to present information on experiences in controlling radiation hazards; and (3) to work out a cooperative program with the States for improving mining conditions and preventing the development and extension of serious health problems.

HISTORICAL BACKGROUND

In 1949 the U. S. Public Health Service, in cooperation with the Atomic Energy Commission and the State Health Departments in the Colorado plateau area, began an investigation of the health hazards that might be associated with the rapidly developing uranium mining industry. While one would expect these miners to be exposed to the usual mining hazards, there were real questions as to whether uranium or its radioactive decay products might present new and additional dangers. Earlier experience in the mines of Germany and Czechoslovakia had shown that miners of uranium-containing ores had had a very high mortality from lung cancer. Whether the lung cancer that developed in these European miners was the result of exposure to radiation in the mines or whether it was due to other environmental or ethnic factors has been a matter of some dispute, but the warning of potential trouble could not be ignored. When early measurements in the American mines showed that levels of radiation approximated those reported from the European mines, it was apparent that careful studies were indicated.

SOURCES OF RADIOACTIVITY

As a result of radioactive decay occurring over millions of years, the uranium ores have associated with them small amounts of radium. One of the decay products of radium is very heavy radioactive gas, radon. Radon, in turn, decays through a number of steps to radium D, and eventually to stable, non-radioactive lead. These decomposition products of radon are known as "radon daughters." The radon, together with two of the immediate daughter products, radium A and radium C' which emit alpha particles, represent the most serious radiation hazard in the mine environment.

Radon gas entrapped in the ore bodies is released from the ore body at the time of blasting and through seepage through the surface of the ore. The radon, now in the mine atmosphere, continues its decay process through the successive radon daughters, emitting alpha particles during some stages of decay. Radon and its daughters may be inhaled along with the air breathed by the miner. Radon is exhaled, but the daughters are partly retained and the decay process takes place inside the miner's respiratory passages, exposing the bronchi and lungs to large amounts of local radiation. The most significant part of the radiation is due to alpha particles.

How much radiation of this sort represents a "safe" level is the subject of continuing research. In the meantime certain guidelines have been adopted, based upon the best available knowledge. Such an estimate was made in the conference of representatives of seven uranium-mining States held in 1955, at which time it was proposed that 300 micromicrocuries per liter of air be taken as a "working level." This level was believed to be not more than

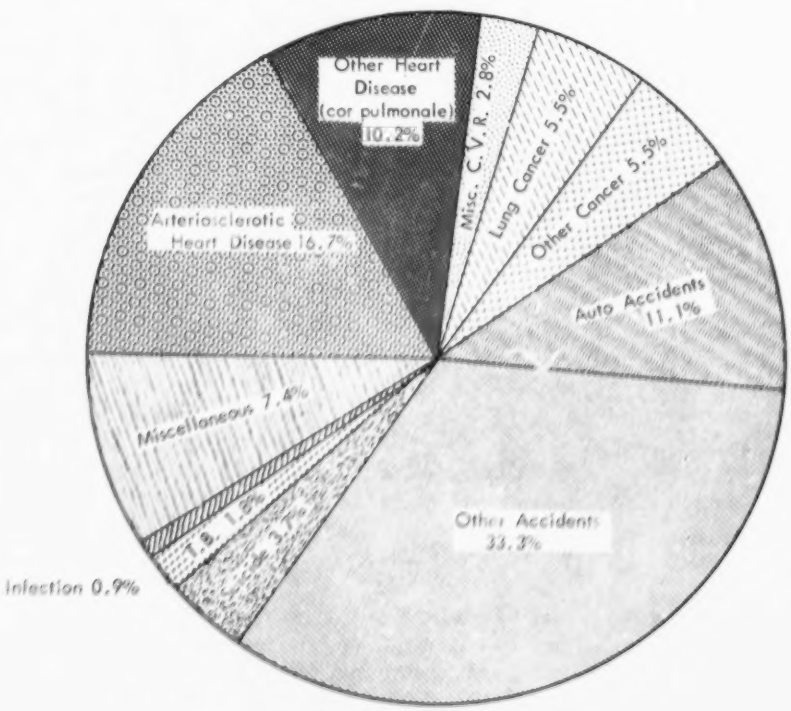
one-tenth of that in the German and Czechoslovakian mines, and, based on the knowledge then available, it was estimated that a worker exposed to this level for a period of forty hours a week over his working lifetime would not suffer biologic damage. This same standard is more precisely stated as 1.3×10^5 Mev of potential alpha energy per liter of air, which is equivalent to the energy released by the complete decay of 100 micromicrocuries per liter of each of the three daughter products, RaA, RaB, and RaC through RaC'. In the subsequent discussion this will be referred to as the "working level."

MEDICAL STUDIES

The Public Health Service, the Atomic Energy Commission, and the cooperating States have examined since 1950 a total of 3,317 uranium miners with an aggregate observation of almost 13,000 person-years. This group includes only 131 miners who have been followed for as long as 10 years. Eastern European experience required exposures of over 15 years to show a significant increase of lung cancer.

CHART 1

URANIUM MINER STUDY
1950 THROUGH 1959 EXPERIENCE



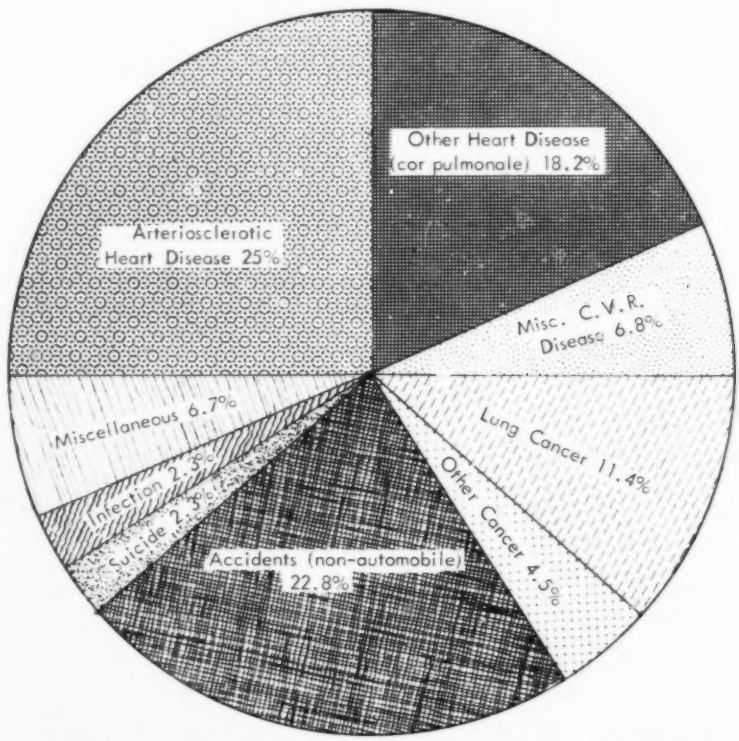
Total Group of 3317 Miners
% of Total Deaths (108) by Cause

Chart 1 shows the crude percentage breakdown of the causes of 108 miner deaths occurring in this group over the 10 year period. Auto accidents, other accidents, and suicides account for almost half of the deaths of these miners. More than half of the "other accidents" group represent various types of mining accidents. The group marked "10.2%, other heart disease" represents primarily a heart disease complication of silicosis. Lung cancer represents 5.5% of the gross mortality.

Chart 2 concerns the white miners who have had more than three years of underground experience. Among these 907 miners, there have been 44 deaths. Various types of cardiovascular renal disease grossly account for half the deaths in this group. Arteriosclerotic heart disease accounts for a quarter; other heart disease, namely, cor pulmonale, 18.2%. Lung cancer has increased to 11.4% of the total deaths.

CHART 2

URANIUM MINER STUDY
1950 THROUGH 1959 EXPERIENCE



907 White Miners With More Than Three Years Underground Experience
% of Total (44) Deaths by Cause

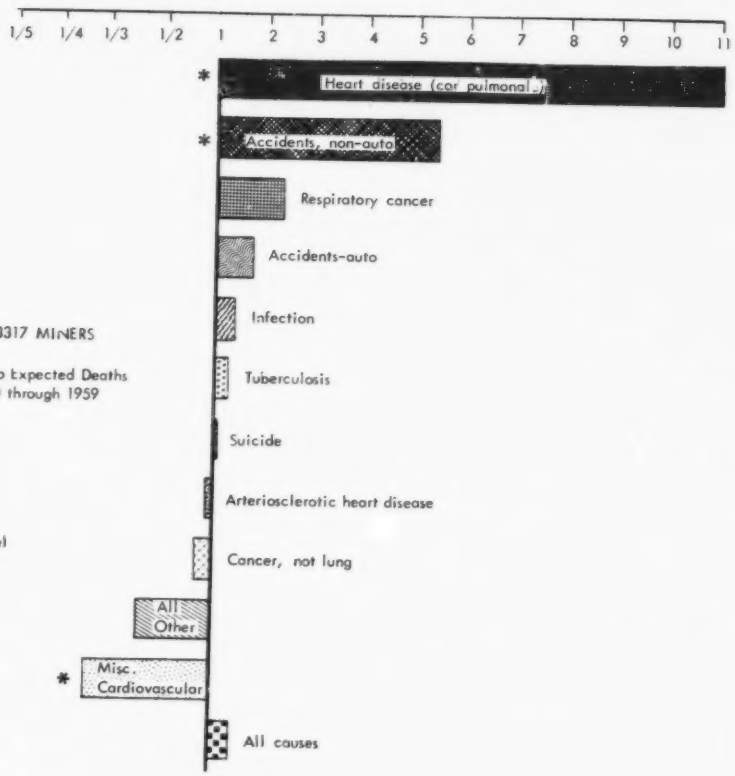


CHART 3

ENTIRE GROUP OF 3317 MINERS

Ratio of Observed Deaths to Expected Deaths by Cause of Death, 1950 through 1959

* Significant at 5% level

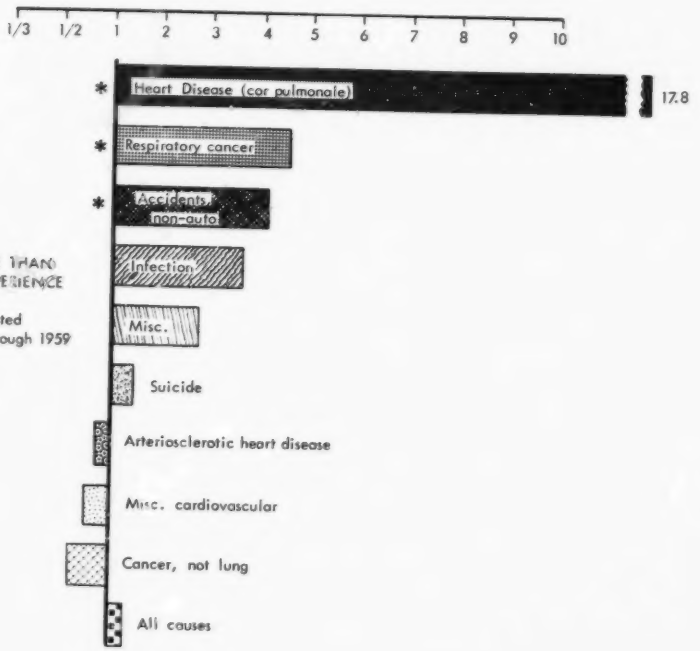


CHART 4

907 WHITE MINERS WITH MORE THAN THREE YEARS UNDERGROUND EXPERIENCE

Ratio of Observed Deaths to Expected Deaths by Cause of Death, 1950 through 1959

* Significant at 5% level

The ratio of observed deaths to expected deaths by cause of death is shown in chart 3*. Leading the list is heart disease, cor pulmonale. This complication is causing eleven times the number of deaths that may be expected from this cause of death. The non-automobile accidents are roughly 5½ times the expected number. Asterisks indicate that these figures are statistically significant.

The three statistically significant causes of death among the 907 white miners who had more than three years of underground experience are shown in chart 4. These are heart disease, with cor pulmonale up to 17.8 times the expected rate; respiratory cancer, nearly 5 times; and the non-automobile accidents, about 4½ times what may be expected. The other death ratios are near the expected rate, the vertical line representing mortality expected in the standard population.

In 1957, triennial medical examinations included for the first time an analysis of the sputa for cancer cells. The technique used (Papanicolau) is similar to that for the detection of cancer of the cervix. Of the 1,075 miners examined (chart 5), 1,061 fell into Classes I and II, essentially negative; 13, or 1.2%, into Class III, representing the doubtful category; and one case, or 0.09%, into Classes IV and V, considered by cytologists to be positive for these cancer cells. In 1960, 1,788 miners were examined with this technique. As of December 9, 1960, reports were available on the first 272. These included 230 negative; 33, or 12.1%, in Class III; and 9, or 3.3%, in Classes IV and V.

CHART 5

EXAMINATION OF SPUTUM FOR SUSPECTED CANCER CELLS

Year	Total	"Negative" Class I & II	"Doubtful" Class III	"Positive" Class IV & V
1957	1075	1061	13 (1.2%)	1 (0.09%)
1960	272 (Examined to date of 1788 taken)	230	33 (12.1%)	9 (3.3%)

*The standard population comparison group used here is the male population of the four States of Arizona, New Mexico, Utah, and Colorado. The specific death rate and age specific death rates for the control population have been calculated and adjusted so that the two groups are comparable. The data for a more significant comparison group of miners working in mines other than uranium are presently being developed from a similar study which has been under way since 1954. This basis will be available for comparison purposes soon.

The precipitous rise from 1957 to 1960 in Classes III, IV, and V cannot be explained by variations in the technique used. Its ultimate significance remains to be determined. Cytologists have found that, in other population groups examined with this technique--primarily hospital population groups, those in Classes IV and V have at least an 80% chance of having bronchogenic carcinoma. They indicate that the percentage in Class III is considerably less, estimates ranging from 20% to 60%. It is not known whether these percentages are valid in the miner population under study. Discussion with health officers has emphasized the importance of organizing a careful follow-up of the men falling into the critical classes.

CONTROL OF RADIOACTIVE CONTAMINANTS IN UNDERGROUND URANIUM MINE AIR

The problem of controlling airborne radioactive contamination is not greatly different from the problems of controlling the concentration of methane in coal mines or dust containing free silica in other types of mines. Adequate ventilation is the primary control measure. Through numerous surveys and inspections by various agencies, efforts have been made both to evaluate the extent of the radiation hazard and to assure compliance with recommended control measures. Most of the results of the measurements have been reported to the U. S. Public Health Service, where the data have been compiled and tabulated as shown in charts 6 and 7 for the years 1958 and 1959. Although these data are voluminous, they must be regarded as merely indicative. They are not definitive for most mines as sampling has not usually been done on a systematic basis.

In 1959, 371 underground mines with 3,619 miners were studied. Thirty-three percent of the 1,802 samples taken of the mine atmosphere had concentrations of less than one times the working level; 22 percent had between 1 and 3 times the working level; 23 percent had between 3 and 9 times the working level, an increase of 2 percent over the preceding year; and 22 percent, 4 percent more than in 1958, had concentrations of more than 10 times the working level (charts 6 and 7).

In July 1959, at the request of the Atomic Energy Commission, the U.S. Bureau of Mines began inspecting uranium mines on public land withdrawn by the Atomic Energy Commission and leased to mine operators. Quarterly physical inspections of the mines were made to observe practices, equipment, and facilities relative to health and safety hazards and to recommend improvements necessary to comply with mine health and safety standards. These inspections were similar to those of other mines, except that particular attention was given to radiation measurements and ventilation, and were in addition to those made by the Colorado Bureau of Mines. The Atomic Energy Commission made follow-up inspections to see that the Bureau's recommendations were carried out.

CHART 6

SUMMARY OF 1958 UNDERGROUND RADON DAUGHTER MEASUREMENTS

State	Total No. U.G.Miners Found in Census	Total No. U.G.Mines Found in Census	No. of Mines Reporting Samples	Total No. of Samples Reported	% of Samples in Each W.L. Range Working Level = 300 μμc of total alpha emitters/liter of air — Multiple of Working Level Ranges				Median Working Level
					< 1	1.1 to 2.9	3.0 to 9.9	≥ 10	
Arizona	148	17	15	103	17	12	27	44	8.3
Colorado	1267	219	4	28	-	37	37	28	4.6
Montana	35	3							
New Mexico	700	29	27	222	50	22	19	9	1.0
Oregon	72	1	1	8	12	38	50	-	3.0
South Dakota	34	4							
Utah	874	115	12	118	28	49	14	9	1.5
Wyoming	14	1							
Total	3144	389	59	479	33	28	21	18	1.8

CHART 7

SUMMARY OF 1959 UNDERGROUND RADON DAUGHTER MEASUREMENTS

State	Total No. U.G.Miners Found in Census	Total No. U.G.Mines Found in Census	No. of Mines Reporting Samples	Total No. of Samples Reported	% of Samples in Each W.L. Range Working Level = 300 μμc of total alpha emitters/liter of air — Multiple of Working Level Ranges				Median Working Level
					< 1	1.1 to 2.9	3.0 to 9.9	≥ 10	
Arizona	220	24	21	80	25	25	30	20	2.9
Colorado	1208	195	159	585	21	17	26	36	6.1
Montana	14	3							
New Mexico	1333	43	41	717	44	25	18	13	1.5
Utah	770	95	78	414	32	24	25	19	2.5
Wyoming	74	11	3	6	17	33	33	17	2.9
Total	3619	371	302	1802	33	22	23	22	2.5

Two types of radiation were measured. One, gamma radiation, similar in effect to X-rays, was found in intensities below the present standards. The second type measured was radioactivity from radon daughters, representing the important radiation hazard in uranium mines. Tests are made on grab samples of mine air taken in all important work areas and therefore represent only the condition at the time and place sampled.

Of the original 17 underground mines under observation, five have discontinued operations. None closed as a result of health and safety hazards. However, there have been occasions when the Atomic Energy Commission has temporarily closed portions of a mine until corrective measures were completed. Open-pit mines were also inspected, but no radiation hazards were found. Experience indicates that it would be unusual to find a radiation hazard either from gamma radiation or radon daughters in such mines, which produce approximately one-third of domestic uranium ore.

In the first inspections the Bureau found the situation regarding radon daughter products as follows:

(a) In two mines no concentrations greater than one times W. L. (working level), the present acceptable concentration, were found.

(b) In two mines the maximum concentration was between one and three times W. L.

(c) In six mines the maximum concentration was between three and ten times W. L.

(d) In seven mines the maximum concentration was more than ten times W. L.

The lessees were required to take appropriate measures to alleviate the hazards found during inspection.

The principal method for reducing concentration of radon daughters was by diluting and flushing the contaminants out of the mine with air. Sealing off inactive areas to restrict flow of radon from them into the air going to work places was another control measure.

By May 1960, the situation in the 13 mines still operating had improved:

(a) In eight mines no concentrations greater than one times W. L. were found.

(b) In two mines the maximum concentration was between one and three times the W. L.

(c) In one mine the maximum concentration was between three and ten times the W. L.

(d) In two mines the maximum concentration was greater than ten times the W. L.

Sampling in September 1960 showed no concentrations greater than three times the working level.

The benefits derived from such inspection-enforcement projects are summarized as follows:

(a) In every mine inspected that originally had high concentrations, substantial reductions have been achieved. Although some mines have not attained full compliance with the prescribed level, they are approaching this goal.

(b) In many instances health and safety improvements more urgently needed than radiation control have been made.

Preliminary studies of time-weighted, average full-shift exposures of individual mine workers have been made. Results tend to support the validity of spot samples as a measure of exposure level. Further studies are in progress.

The cost of ventilating a uranium mine is difficult to predict, each mine presenting an individual problem. Ventilation costs have been estimated as ranging from ten cents to one dollar per ton of ore produced. Mines having extensive workings and those with high grade ore are more likely to need large quantities of airflow. Non-extensive mines which have small quantities of ore are not likely to need as costly a system.

In some uranium mines, positive airflow of 15,000 cubic feet per minute will remove contaminants. In other uranium mines as much as 50,000 cubic feet of air per minute is required, and on rare occasions 100,000 or more is needed. The exact requirement for each mine has to be determined from sampling results and physical layout.

Mechanical ventilation is essential in virtually all uranium mines to reduce radiation to the acceptable level. Natural ventilation may be a useful adjunct to mechanical ventilation, but it cannot be relied upon for dependable control. To be effective, airflow must be coursed to sweep the place being ventilated. Maximum benefit from a specific quantity of airflow is obtained when uncontaminated air is delivered through a tube or a drill hole directly to the work place. When air is coursed from the mine adit or shaft through the passageways to the work places, it can pick up

radon daughters; therefore, more air is needed to produce the same effect. Coursing of air through passageways is common practice in ventilating uranium mines because large quantities of air can be moved with less power consumption than would be needed to force small quantities of air through tubing or drill holes.

A convenient rule for determining the quantity of airflow needed to reduce the radon daughter contamination to one working level is that the quantity of air needed equals the quantity of air at existing conditions times the square root of the radon daughters working level at the existing conditions.

There are nearly 1,000 active underground uranium mines in the Western United States. It is believed that in virtually all uranium mines radioactive contamination can be controlled, and that the means of control is practicable. Determination of the means of control applicable to each mine can be determined only by individual study.

AVAILABLE ASSISTANCE FROM FEDERAL GOVERNMENT

States may seek various types of aid from Federal government agencies. Among these, the Department of Labor may assist in connection with enforcement of the Public Contracts Act, which applies to all Federal supply contracts in excess of ten thousand dollars. The safety and health provisions of the Act are very general, stating that performance on the contract must be under safe and sanitary conditions. In the absence of a definite Federal code with regard to uranium mining, the administration or enforcement of the Public Contracts Act so far as safety and health are concerned is dependent upon State regulation and enforcement. If the State should desire to extend enforcement in uranium mines under the aegis of the Act, the Department of Labor would cooperate in supplementing the State's work.

In 1944 the Bureau of Mines of the Department of the Interior was assigned the responsibility for inspecting all mines on Indian lands and the public domain. The Bureau also has undertaken the inspection of uranium mines operating under lease from the Atomic Energy Commission. Inspections include observation of such factors related to health and safety of operations as ventilation, dust control, air quality, ground support, use of explosives, haulage, hoisting, fire hazards, and, in the case of underground uranium mines, radiation hazards.

The Bureau of Mines prepares inspection reports which contain recommendations for correction of any potential hazards to health and safety. If concentrations of radon decay products

greater than the working level suggested by the Public Health Service are found during inspections, the reports contain calculated estimates of the rates at which ventilation should be supplied to reduce radiation to the acceptable level. These reports are available to agencies which have justified interest in the findings. The Bureau of Mines acts in an advisory capacity and has no authority to enforce corrective measures. Authority of the Department of the Interior for enforcing correction of hazards in mines on Indian lands and the public domain is vested in the Geological Survey through provisions of Government leases.

The Bureau of Mines does not have the right to enter uranium mines on privately-owned lands, but, if requested to do so by management, will extend to such mines similar inspection services. The Bureau is prepared to provide to Federal and State agencies, to the mining industry, and to employee organizations, technical advice, assistance, and information on matters pertaining to the promotion of safe and healthful working conditions in mines, and, within the limits of its facilities, to undertake research or investigations dealing with special problems in this field.

Courses of training are extended to supervisors and workers in the industry. Such courses are adapted to provide information on the particular hazards that may be encountered in a given mine or that may be associated with a given method or type of mining.

The Atomic Energy Commission, under the Atomic Energy Act of 1954, licenses possession and use of source materials, and requires licensees to abide by the standards set forth in Title 10, Chapter 1, Part 20 of Standards of Protection Against Radiation. This authority is not regarded as extending to control of radiation hazards within uranium mines.

The Commission is cooperating with the Bureau of Mines in attempting to bring the level of mine contamination down to the working level in those uranium mines which are under its control. This experience should be a useful guide to private mines with similar problems.

The Atomic Energy Commission is also prepared upon request to offer technical advice and assistance on radiation problems associated with the mining of uranium.

The Department of Health, Education, and Welfare is prepared to assist States in the following ways:

(a) To assign a coordinator to work with the various States in identifying the most serious trouble spots; provide administrative advice and technical assistance; coordinate resources of the

Public Health Service and other Federal agencies concerned; maintain a complete file of reports on radiation hazards and other pertinent data; and assist the States generally in expediting their control programs.

(b) To make special studies of radiation problems in government-controlled mines, in cooperation with the U.S. Geological Survey, the Bureau of Mines, and the Atomic Energy Commission, and conduct similar studies of private mines on request.

(c) To begin work on the development of special control techniques and conduct demonstration studies of different mining methods to determine the most effective control methods.

(d) To conduct training courses for operators, mine foremen, and State personnel and prepare and distribute educational reports, pamphlets and other materials to aid the mine operators in developing better control methods.

(e) To establish, in cooperation with State health authorities, diagnostic facilities where special medical examinations of uranium miners could be performed.

(f) To accelerate and extend, in cooperation with State health authorities, the medical examination program for uranium miners.

Other services, contingent upon budget and staff considerations, would include the assignment of personnel to States having a large number of uranium mines and the undertaking of cooperative projects to help uranium-producing States increase their own resources for intensified control programs.

STATE OBJECTIVES

The following objectives, directed toward a solution of the serious health problems presented by excessive radioactivity in uranium mines, were outlined by State authorities:

(a) Follow up the miners reported to date with cytologically positive sputa tests for more definitive diagnosis and any necessary treatment.

(b) Examine all uranium miners who have not yet received a physical examination.

(c) Increase inspections of mines, in both frequency and intensity. Allareas in each mine should be surveyed, and inspections should be made more frequently to compensate for seasonal variations in ventilation and changes in concentration levels caused by mining activity.

(d) Check compliance with control recommendations.

(e) Carry out additional research to evaluate mining exposures and their health effects.

(f) Provide more consultative and educational services to mine personnel directed toward the establishment of effective control measures and self-monitoring programs.

(g) Enforce existing laws and standards and determine if new laws are needed.

(h) Accelerate State training programs and participate in those offered by other agencies.

IMMEDIATE ACTION PROPOSED

An organization of the States involved in uranium mining to work out the practical aspects of the study and control program might be formed. It was suggested that this responsibility could be carried out either through an informal organization or through the Council of Western States. The problem will also be scheduled for discussion at the Western Governors' Conference, to be held in May 1961.

The Department of Health, Education, and Welfare suggested that the governors may wish to meet again with Federal agency representatives during 1961 to exchange information leading to the development of uniform programs.

CONCLUSION

Mounting evidence is pointing to the existence of severe health hazards in uranium mines. Control of these hazards was viewed by the conferees as a primary responsibility of the States, and more aggressive action is planned to meet the problem. Upon request, various agencies of the Federal Government can provide assistance to the States in carrying out this responsibility.

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